Vibration Report

LINDEN AVENUE AND CASITAS PASS ROAD INTERCHANGES PROJECT

Casitas Pass Road to Linden Avenue

SB-101-PM 2.2/3.4
EA 05-4482U0

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Caltrans

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Introduction

The California Department of Transportation (Caltrans) proposes to make operational improvements to Route 101 within the City of Carpinteria, in Santa Barbara County. The project includes reconstructing the Linden Avenue and Casitas Pass Road interchanges, reconfiguring on- and off-ramps, replacing Route 101 bridges over Carpinteria Creek, extending Via Real frontage road from Bailard Avenue through to Casitas Pass Road, adding a new bridge over Carpinteria Creek at Via Real, and reconstructing bike paths. The proposed action will take place on Route 101 and adjacent streets from west of Franklin Creek to just east of Carpinteria Creek. The project area is approximately one mile in length. The project is needed to reduce existing and projected congestion in this area.

The purpose of this report is to review the potential vibration impacts from the proposed project. Caltrans has had extensive experience with highway traffic and highway construction related activities, and realizes the potential for some of these activities to cause annoyance and damage at residences near the highway. The current study is based on a literature search of previous vibration reports produced by Caltrans, and on <u>Transportation and Construction-Induced Vibration Guidance Manual</u> (Caltrans Environmental Program, June 2004). The current study places emphasis on informing the public about construction-related vibrations, and of establishing minimization measures that will protect residences and businesses near the highway to the extent possible, from construction-related vibrations.

Build Alternatives

The proposed project has four build alternatives. Alternatives 1 and 4 are similar, and Alternatives 2 and 3 are similar. All alternatives would replace the Carpinteria Creek bridges, and construct a new bridge for Via Real across Carpinteria Creek. All alternatives would share the same alignment southeast of Vallecito Road. Table 1 compares the four alternatives.

Alternatives 1 and 4

The major feature of Alternatives 1 and 4 is that they would extend the northbound on-ramp across Franklin Creek Bridge to bring it up to current design standards. The northbound bridge will be replaced with a wider bridge of the same length to accommodate the northbound on-ramp. The new on-ramp would not loop under the Linden Avenue structure as does the existing on-ramp, and as would Alternatives 2 and 3. The difference between Alternative 1 and 4 is that Alternative 1 affects slightly more of the Verizon Property located just east of the Via Real and the Linden Avenue Interchange.

Alternatives 2 and 3

Alternates 2 and 3 do not cross or replace the northbound Franklin Creek Bridge. Both Alternatives 2 and 3 would mimic the existing loop northbound on-ramp. Alternative 2 would have a standard intersection with Via Real slightly off-set from the intersection of Ogan Road, while Alternative 3 would create a roundabout intersection with Via Real, Ogan Road and the northbound (loop) on-ramp meeting about 400-feet east of the junction of Via Real and Linden Avenue.

No-Build Alternative

The no-build alternative would not upgrade the Linden Avenue and Casitas Pass Road Interchanges; would not reconstruct either the Carpinteria Creek or Franklin Creek Bridges, and would not connect Via Real between Bailard Avenue and Linden Avenue. The grade of the highway would also be unaffected.

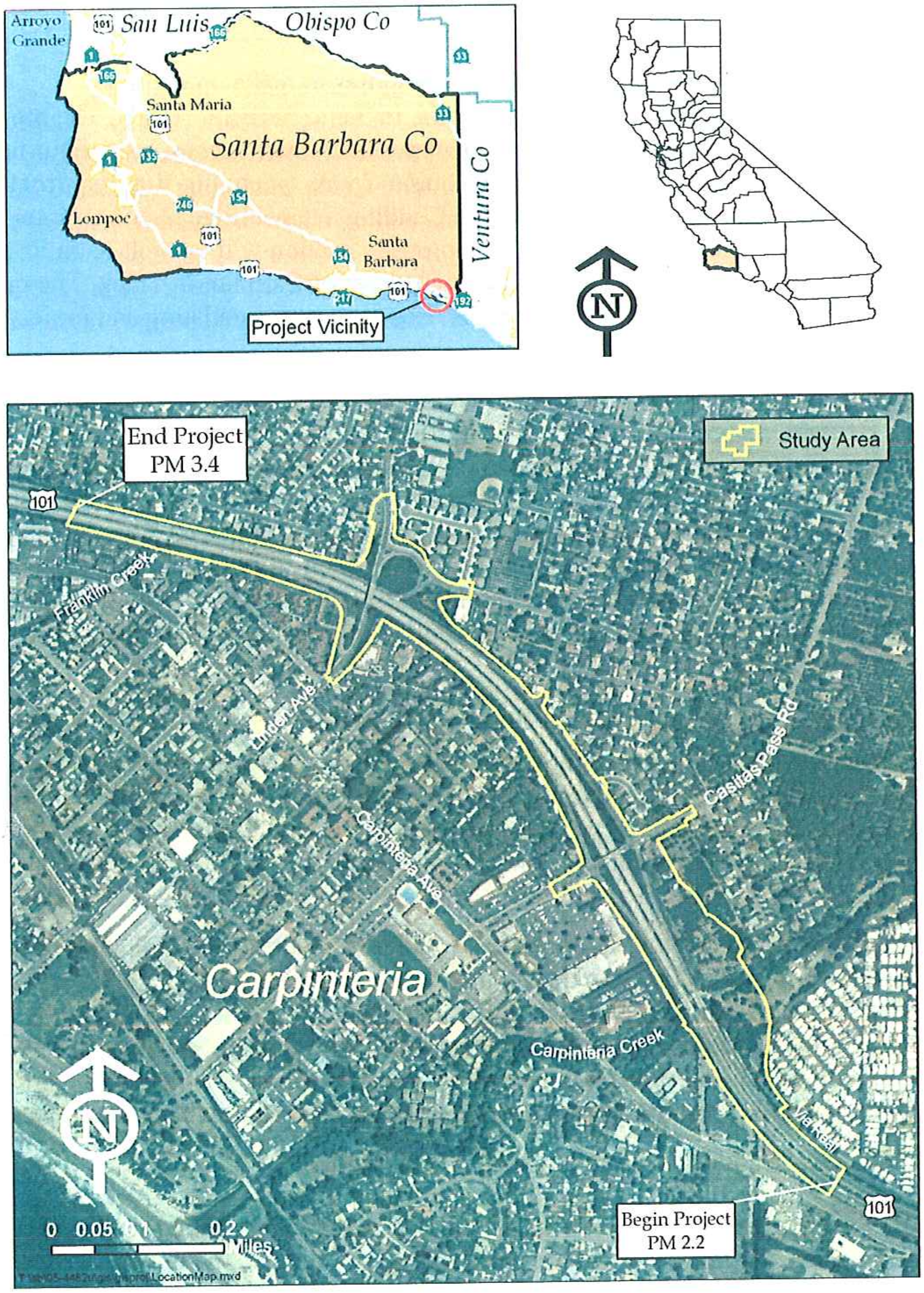


Figure 1—Project Location Map

Table 1—Comparison Of Proposed Build Alternatives

DESCRIPTION	ALT. 1	ALT. 2	ALT. 3	ALT. 4
Replace existing 2-lane Casitas Pass Road over-crossing with 5-lane over-crossing, including bike lanes and 5-foot sidewalks	X	X	X	X
Upgrade southbound on and off-ramps at Casitas Pass Road OC	X	X	X	X
Construct new northbound on and off-ramps at Via Real south of Casitas Pass Road OC	X	X	X	X
Extend Via Real as a frontage road between mobile home park across Carpinteria Creek to Linden Avenue	X	X	X	X
Replace and widen northbound and southbound Route 101 bridges over Carpinteria Creek	X	X	X	X
Construct new 2-lane bridge over Carpinteria Creek on Via Real	X	X	X	X
Remove northbound cloverleaf on-ramp at Linden Ave	X	X	X	X
Remove northbound on ramp at Vallecito Avenue	X	X	X	X
Replace existing 2-lane Linden Avenue over-crossing with 4-lane over-crossing including bike lanes and 5-foot sidewalks		X	X	
Replace existing 2-lane Linden Avenue over-crossing with 5-lane over-crossing including bike lanes and 5-foot sidewalks	X			X
Replace northbound on-ramp and southbound off-ramp at Linden Ave.	X	X	X	X
Replace northbound Franklin Creek Bridge.	X			X
Signalize intersections at: 1) Casitas Pass southbound on-ramp and off-ramp, 2) Casitas Pass northbound on and off-ramps at Via Real, 3) Casitas Pass Road/Via Real, 4) Linden Avenue/Via Real, 5) Linden Avenue northbound on-ramp, and 6) Linden Avenue southbound off-ramp.	X	X	X	X
Repave and raise the profile of Route 101 from the south project limit to just north of Casitas Pass Road over-crossing	X	X	X	X
Median planting: oleander, *photinia, raphiolepsis, plumbago, palms.*	X	X	X	X

Vibration Basics

Vibration is the result of the propagation of energy waves through a medium (see Figure 2). The medium can be solid, liquid or gas, thus vibration can be earth-borne or airborne. Noise is a type of vibration, because it is created by energy waves striking a sensitive medium—the eardrum. In transportation-related activities, these waves can be generated by tires crossing uneven pavement or construction activities like pile driving, pavement breaking, use of explosives or vibratory rollers.

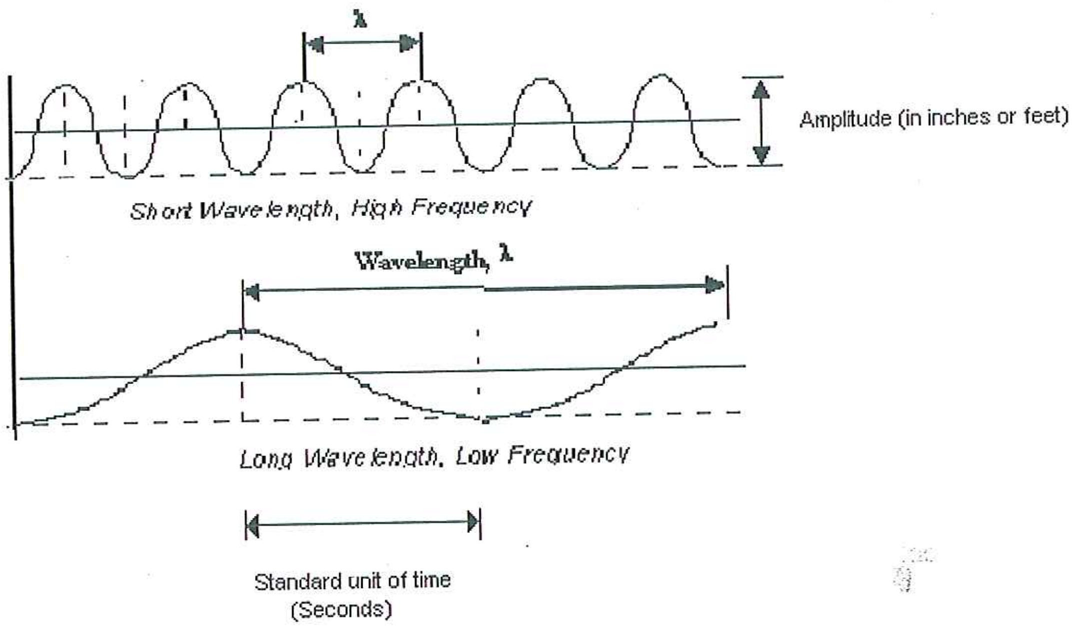


Figure 2—Illustration of Wavelength, Frequency and Amplitude

The formula for propagation of this energy wave is:

frequency (f) =wave velocity (c) /wavelength.

The resultant of this formula is the peak particle velocity (PPV in inches per second or millimeters per second). Vibrations are experienced in three different types of waves: Rayleigh (surface waves that have a vertical particle movement), spherical (P) waves (that spread like sound), and spherical-transverse (S) waves. Of these, the most often felt waves are the Rayleigh waves.

Sources of earth-borne vibrations may include natural phenomena (earthquakes, volcanic eruptions, sea waves, landslides, etc.), or manmade causes (explosions, machinery, traffic, trains, construction equipment, etc.). Vibration sources may be continuous (such as factory machinery), or transient, (like explosions). Earth-borne vibrations may be described by amplitude and frequency. Amplitude is described by the log of the square of the ratio of pressure fluctuations around mean air pressure divided by a reference pressure, and is expressed in logarithmic units of decibels. Referring to earth-borne vibrations, amplitude is described by the local movement of soil particles. This movement should not be confused with "wave velocity."

To distinguish between wave velocity and particle motion, consider the analogy of ripples on a lake and a floating cork. Wave velocity is analogous to the velocity of the ripples. In air, the wave velocity is the speed of sound. Particle motion may be compared to the bobbing of the cork as the ripples pass by. The bobbing of the cork represents the local movement of the soil particles as earth-borne vibration waves pass through the soil.

Transportation Related Vibration

Most Caltrans projects are concerned with three types of transportation-related earth-borne vibration sources:

- Normal highway traffic – heavy trucks, and quite frequently buses, generate the highest earth-borne vibrations of normal traffic. Vibrations from these vary with pavement conditions. Potholes, pavement joints, rocking slabs, differential settlement of pavement, etc., all increase the vibration levels.
- Light and heavy rail operations – diesel locomotives, heavily loaded freight cars, and operations such as coupling create the highest rail traffic vibrations.
- Construction equipment – pile driving, pavement breaking, blasting, and demolition of structures generate among the highest construction vibrations.

There are no Federal Highway Administration (FHWA) or state standards for vibrations. The traditional view has been that highway traffic and most construction vibrations pose no threat to buildings and structures, and that annoyance to people is no worse than other discomforts experienced from living near highways.

Of the three transportation vibration sources listed above, construction vibrations are of greatest concern. The four operations mentioned under construction equipment (pile driving, pavement breaking, blasting, and demolition of structures) are potentially damaging to buildings at distances of less than 25 feet from the source.

With the exception of some construction operations such as pile driving, pile hole drilling, and perhaps some deep excavations, all vibrations generated by construction and operation of surface transportation facilities are mainly in the form of surface or Rayleigh waves

A considerable amount of research has been done to correlate vibrations from ***single events*** such as dynamite blasts with architectural[1] and structural[2] damage. The U.S. Bureau of Mines has set a "safe blasting limit" of 2 in/sec. Below this level there is virtually no risk of building damage from a single event.

Safe levels for ***continuous*** vibrations from sources such as traffic are not as well defined. The Transport and Road Research Laboratory in England has researched continuous vibrations to some extent and developed a summary of vibration levels and reactions of people and the effects on buildings (Table 2). These are the criteria used by Caltrans to evaluate the severity of vibration problems. Traffic, train, and most construction equipment-produced vibrations (with the exception of pile driving, blasting, and some types of demolition) are considered continuous.

1 Cracking of plaster, tile or stucco.
2 Weakening of structural members of the house.

Table 2—Vibration Level and Intensity

Vibration Level			
Peak Particle Velocity mm/sec	Peak Particle Velocity in/sec	Human Reaction	Effect on Buildings
0.15 to 0.3	.006 to .019	Threshold of perception – possibility of intrusion	Vibrations unlikely to cause damage of any type
2.0	0.08	Vibrations Readily Perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
2.5	0.10	Level at which continuous vibrations begin to annoy people[3]	Virtually no risk of "architectural" damage to normal buildings
5	0.20	Vibrations annoying to people in buildings (this agrees with the levels established for people standing on bridges and subjected to relatively short periods of vibrations)	Threshold at which there is a risk of "architectural" damage to normal dwelling – houses with plastered walls and ceilings Special types of finish such as lining of walls, flexible ceiling treatment, etc., would minimize "architectural" damage
10 to 15	0.4 to 0.6	Vibrations considered unpleasant by people subjected to continuous vibrations and unacceptable to some people walking on bridges	Vibrations at a greater level than normally expected from traffic, but would cause "architectural" damage and possibly minor structural damage

Source: A Survey of Traffic-Induced Vibrations by Whiffen, A.C. England, 1971

Annoyance levels in this table are subjective and can vary depending on the activity level of the observer. Annoyance can occur at lower peak particle velocities for more sedentary observers.

The numbers in the first 2 columns on the left are based on the peak particle velocity in the vertical direction (Rayleigh waves). Where human reactions are concerned, the value is at the point at which the person is situated (no set distance from the source). For buildings, the value refers to the ground motion but no allowance is included for the amplifying effect of structural components.

The "architectural damage risk level" for continuous vibrations (peak vertical particle velocity of 5 mm/sec or 0.2 in/sec) shown on Table 2 is one tenth of the maximum safe level of 50 mm/sec (2 in/sec) for single events.

Very little information is available concerning the damaging effects of pile driving. Although technically a series of single events, pile driver blows occurring often enough in a confined area could cause damage at a lower level than the single event criterion of 2 in/sec. Pile driving levels often exceed 0.2 in/sec at distances of 50 feet, and 0.5 in/sec at 25 feet. Pile driving has been done frequently at these distances (50 feet and 25 feet) without structural damage to buildings. The 2-in/sec single event criterion is still being used by some organizations and engineering firms as a safe level for pile driving. Although never measured by Caltrans, calculations show that this level (2 inches/second) will probably be exceeded within 6 feet of a 50,000-ft. lb.[4] pile driver. This level is probably a safe criterion to use for well engineered and reinforced structures. *For normal dwellings, however, pile-driving peaks should not be allowed to exceed 0.4 in/sec at about 50 feet from the source.*

Caltrans' general experience has been that almost never are traffic-generated vibrations damaging to structures near the highway. Construction generated vibrations, however, can exceed the point of damage. Tables 2 and 3 illustrate this point—compare the peak particle velocity from pile drivers and pavement breakers at 25 feet (Table 3) to the effect on buildings (Table 2).

4 One foot-pound is the amount of energy expended when a force of one pound acts through a distance of one foot along the direction of the force.

Table 3—Vibration Source Levels For Construction Equipment

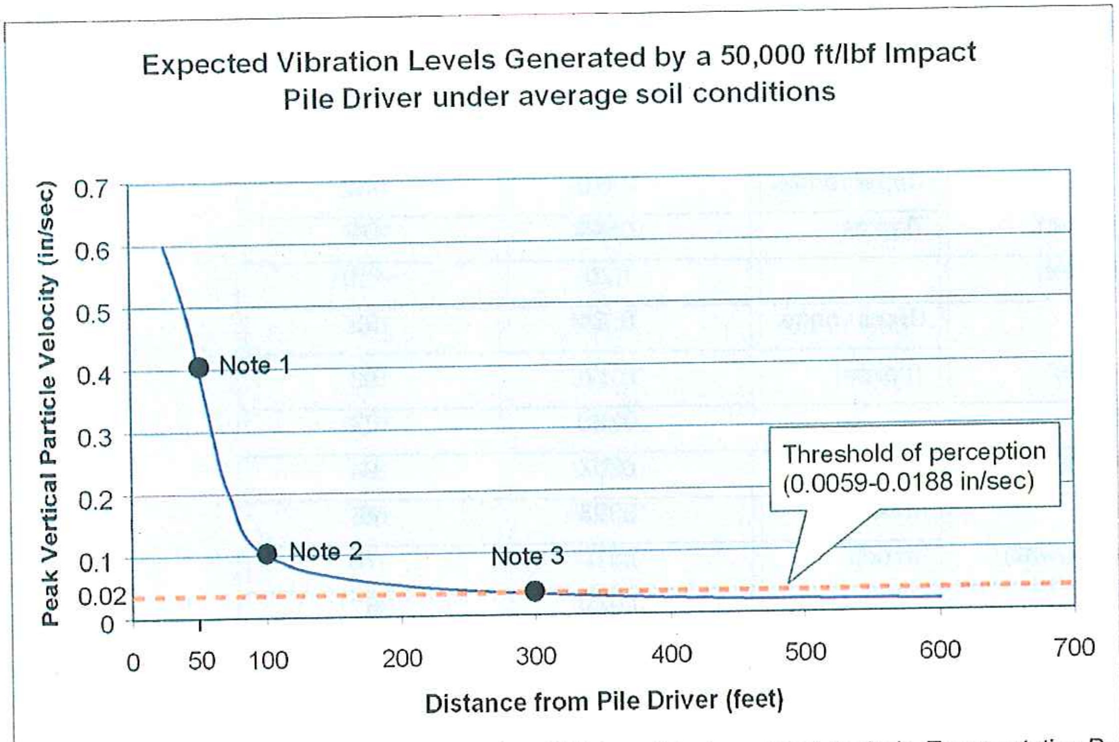
Equipment		PPV (in/sec) at 25 ft	Approximate Lv† at 25 ft.
Pile Driver (impact)	Upper range	1.518	112
	Typical	0.644	104
Pavement Breaker		1.25	~110
Pile Driver (sonic)	Upper range	0.734	105
	Typical	0.170	93
Vibratory Roller		0.60	103
Clam shovel drop (slurry wall)		0.202	94
Hydro-mill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

Source: ntl.bts.gov/data/rail05/ch12.pdf

† RMS (Root mean square) velocity in decibels (VdB) re 1 micro-inch/second. Comparable to decibels used in noise measurement.

All damage criteria for buildings are in terms of ground motion at the buildings' foundations. No allowance is included in Table 2 for the amplifying effects of structural components. Obviously, the way a building is constructed and the condition it is in determines how much vibration it can withstand before damage appears. Table 2 shows a recommended upper level of 0.08 in/sec for continuous vibrations to which "ruins and ancient monuments" should be subjected. This criterion level may also be used for historical buildings, or buildings that are in poor condition.

Figure 3 shows how typical pile driving vibrations decrease with distance, for a 50,000 foot – pound energy impact pile driver in average soil conditions. Clay soils provide more resistance to advancing piles and therefore generate higher vibration levels near the source than those in sandy soils. Vibrations in clay soils, however, tend to drop off more rapidly with distance than those in sandy soils. The architectural damage risk level and the recommended upper level for historical buildings are exceeded at about 50 to 60 feet and 110 feet, respectively.



Source: California Department of Transportation, Division of Environmental Analysis. Transportation Related Earth-borne Vibrations. 2004.

Note 1—vibrations may cause architectural damage (0.4-inches/second ppv—Table 2)
Note 2—continuous vibrations begin to annoy people (0.2-inches/second ppv—Table 2)
Note 3—vibrations may be perceived (~0.02-inches/second ppv—Table 2)

Figure 3—Pile Driver Vibration Attenuation with Distance

The above discussions indicate that in any situation the probability of exceeding architectural damage risk levels for continuous vibrations from construction and trains is very low and from freeway traffic practically non-existent. However, if vibration concerns involve pavement breaking, extensive pile driving, or trains 25 feet or less from normal residences, buildings, or non-reinforced structures, damage is a real possibility. This may also be true if these operations occur within 50-100 feet from historical buildings (unless in excellent condition), buildings in poor condition, or buildings previously damaged in earthquakes.

The outer limits for architectural damage to historical buildings from pile driving, and perhaps from pavement-breaking operations as well, is 50 feet to 100 feet, while the limit for structural damage to most residences is within 25 feet of the vibration source.

There are no historic buildings within 100-feet of any of the proposed pile driving or pavement breaking locations. The historic Ogan House is located 288-feet from the nearest pile driving or pavement breaking location.

While other buildings at these locations are outside the limits for architectural and structural damage, they are close enough to the pile driving sites that the annoyance level from vibrations may be exceeded. Demolition of the overcrossing is slated to occur at night, and vibration impacts may disrupt local residents' sleep.

Proposed Construction Activities

Construction activities resulting from the proposed improvements have the potential to generate noise that can annoy residents up to 800 feet from the highway, and vibrations than can annoy and cause architectural and structural damage to residences and buildings adjacent to the work zone. Those activities include:

1) **Structure Demolition** includes: Carpinteria Creek Bridge (P.M. 2.44), Franklin Creek Bridge[5] (P.M. 3.30), Linden Avenue Overcrossing (P.M. 3.6), and Casitas Pass Overcrossing (P.M. 2.64- see Appendix 1, Sheet A, B1, and B2, and Table 4). Demolition is typically conducted with a hoe ram mounted on a backhoe. Impacts from the hoe ram are similar to those of a pavement breaker, and would very likely generate similar vibrations.

2) **Pavement Breaking** (or cracking and seating) the concrete pavement with a large impact hammer will occur on Highway 101 in both directions between approximately 1000 feet south of the Carpinteria Creek Bridges and 138 feet north of the Casitas Overcrossing in both directions. The total length of the crack and seat operation is about 2400 feet. The entire highway will be raised to accommodate the new Carpinteria Creek Bridge structures that will have a higher clearance over Carpinteria Creek (Appendix 1, Sheet A, Table 4)

3) **Pile-driving** during construction is planned for the abutments at the Linden Avenue and Casitas Pass Overcrossings and at Carpinteria Creek Bridges and Franklin Creek Bridge (see Appendix 1, Sheet A, B1, and B2, and Table 4). These structures will be reconstructed or widened. The pile driving would occur during normal daylight hours, and would last for about eight hours per day.

Pile-driving is also planned during the construction of the retaining walls (Walls E—M), and soundwalls (Soundwalls 1, 2, 3, and 9). These are shown in Appendix 1—Sheets A, B1 and B2, and on Table 4. Final details on footing types will come after the completion of geotechnical studies.

Potential Impacts from Construction

This report documents the current design and proposed construction activities, however, additional options will be evaluated once the geotechnical studies are complete and during the Plans, Specifications and Estimates (PS&E) phase when structures design will determine the feasibility of earth retaining and soundwall foundations (that do not require driven piles) for the retaining walls and soundwalls. One example of these is Mechanically Stabilized Earth (MSE) retaining walls. Structures design will also explore the feasibility of micropile foundations, which are less vibration intensive than the currently planned driven piles for soundwall foundations. The development of alternative foundation types would help minimize potential vibration impacts to residents near the construction project.

Depending on the duration, intensity and timing of the proposed construction activities—structure demolition, pavement breaking and pile driving—may affect residents and structures adjacent to the proposed construction activity. Information presented above was used to estimate the potential for impacts to residents and structures near the proposed construction area. As one would expect, the effects of activities like pile driving and pavement breaking lessen with distance from the source as the energy from the impacts are absorbed by the sub-surface. Three zones of lessening

5 Alternatives 1 and 4 only

intensity have been established to classify the expected impacts from the proposed construction activities.

The 300-foot individual contact zone was derived from Figure 3 that shows the expected vibration level crossing the (dotted) threshold of perception line (0.02 inches per second peak particle velocity about 300 feet from the source). Residents will begin to perceive vibrations at this distance.

The 100-foot contour was selected from Table 2 that shows the level where continuous vibrations begin to annoy people (0.10-inches per second peak particle velocity). Figure 3 shows that this level occurs at about 100 feet from the source.

The 60-foot contour was selected from Table 2 that shows the level where continuous vibrations may cause architectural damage (0.4-inches per second peak particle velocity). Figure 3 shows that this level occurs at about 50-60 feet from the source.

Figure 4 and Appendix 1—Sheets A, B1 and B2 depict the three vibration sensitivity zones and sources and locations of expected vibration within the project limits. Those zones are divided into 60-foot, 100-foot, and 300-foot intervals. Table 4 summarizes potential construction impacts associated with project alternatives and the number of properties potentially affected within the three vibration sensitivity zones.

Table 4—Potential Construction Impacts

Location	Alternative	Activity	Duration	Impacted residences			Impacted residences (1)		
			Days	60 ft	100 ft	300 ft	60 ft	100 ft	300 ft
Linden OC	1, 2, 3, 4	demolition	5	0	0				
Linden OC	1, 2, 3, 4	pile driving (br)	3	0	0				
Casitas Pass OC	1, 2, 3, 4	demolition	5	0	1			*30*	
Casitas Pass OC	1, 2, 3, 4	pile driving (br)	3	0	1			*30*	
Carpinteria Creek Br (L, R)	1, 2, 3, 4	demolition	5	0	0				
Carpinteria Creek Br (L, R)	1, 2, 3, 4	pile driving (br)	3	0	0				
Route 101 from 200 feet north of Casitas Pass Bridge to 2000 feet south	1, 2, 3, 4	pavement breaking	5	2	2		*2, 17*	*2, 17*	
Franklin Creek Br. (1)	1, 4	demolition	5	1	1		*78*	*78*	
Franklin Creek Br. (1)	1, 4	pile driving	3	1	1		*78*	*78*	
Via Real Bridge (new)	1, 2, 3, 4	pile driving	3	0	0				
Soundwall B1 (NB on from Linden)(1)	1, 4	pile driving (sw)	7	1	6		*78*	*78, 79, 80, 90, 97, 98*	
Soundwall B2 (NB on from Linden)	1, 2, 3, 4	pile driving (sw)	10	15	17		*112, 113, 114, 115, 116, 117, 118, 119, 149, 150, 151, 152, 153, 154, 155*	*112, 113, 114, 115, 116, 117, 118, 119, 120, 148, 149, 150, 151, 152, 153, 154, 155*	
Soundwall B3 (Ogan Rd)	1, 2, 3, 4	pile driving (sw)	4	4	9	355	*177,179, 180,187*	*165,166, 177,178, 179,180, 181,186, 187*	See Appendix 2
Soundwall B9 (Sawyer Rd)	1, 2, 3, 4	pile driving (sw)	5	2	7		43, 44	39, 43, 44, 212, 286,	
Retaining Wall E (Via Real)	1, 2	pile driving (rw)	5	0	3			*53, 65, 66*	
Retaining Wall F (Via Real)	3	pile driving (rw)	5	0	3			*53, 65, 66*	
Retaining Wall G (Via Real)	4	pile driving (rw)	5	0	3			*53, 65, 66*	
Retaining Wall H (Via Real)	4	pile driving (rw)	5	1	1		*70*	*70*	
Retaining Wall I (Via Real)	2, 3	pile driving (rw)	5	1	1		*70*	*70*	
Retaining Wall J (SB off to Linden)	2, 3, 4	pile driving (rw)	4	0	3			*193, 237, 240*	
Retaining Wall K (SB off to Linden)	1, 2, 3, 4	pile driving (rw)	4	1	4		*193*	*104,193, 237, 240,*	
Retaining Wall L (Via Real)	1, 4	pile driving (rw)	4	5	7		*112,113, 114,115, 119*	*112,113, 114,115, 116,119, 120*	
Retaining Wall M (Via Real)	1, 4	pile driving (rw)	10	15	17		*112, 113, 114, 115, 116, 117, 118, 119, 149, 150, 151, 152, 153, 154, 155*	*112, 113, 114, 115, 116, 117, 118, 119, 120, 148, 149, 150, 151, 152, 153, 154, 155*	

(1) Refer to Appendix 2 (not included in public release)

Minimization Measures

Vibration Sensitivity zones resulting from pile driving, structure demolition and pavement breaking are divided into 60-foot, 100-foot, and 300-foot intervals. These are depicted on Figure 4 and on Sheets A, B1 and B2 in Appendix 1. Appendix 2 identifies properties within the three sensitivity vibration zones.

To reduce the effects of construction vibration the following measures are recommended:

1. Individually notify residents within 300 feet of areas where pile-driving, and pavement breaking will take place at least two weeks in advance of the proposed activity. Residents may wish to secure fragile items that could be broken by shaking. See Figure 3 for the attenuation of vibration with distance from a pile driving or pavement breaking activity.
2. Arrange motel rooms for residents living within 100 feet of the proposed activity when protracted vibrations in excess of 0.20 inches/second are expected at their residence during hours that they are normally asleep.[6]
3. Conduct a photo or video survey of susceptible areas in advance of the potentially damaging construction work (i.e. when expected vibrations are greater than 0.4 in/sec. within 60 feet of a pavement breaking or pile driving location.)[7] Such activities will occur along the northbound Linden Avenue on-ramp, Ogan Road, Via Real (near the Verizon Switching Center), and residences near the intersection of Sawyer and Holly Lane.
4. Monitor and record peak particle velocities near the sensitive receptors while the highest vibration producing activities are taking place.
5. Use vibratory pile driving when soil and other conditions are favorable for employment of this method. Pre-drill pile-holes, or use CIDH (Cast in Drill Hole) or CISS (Cast in Steel Shell) piles when feasible.
6. Use rubber tired instead of tracked vehicles near vibration sensitive areas.
7. Assure that night joints and bridge conforms are as smooth as possible, especially where there is heavy truck traffic near residences.
8. Perform activities most likely to propagate objectionable vibrations during the day, or at least before most residents retire for the night.
9. Pavement breaking shall be restricted to daylight hours.
10. Nighttime demolition work will be limited to removal of the Linden Avenue and Casitas Pass Overcrossings.
11. All pile driving shall be done during daylight hours.

6 Refer to Table 1 that shows the level at which continuous vibrations can disturb an individual's sleep, and Table 4 that shows the residences that are anticipated to be within the 100-foot zone.

7 This assessment is based on the upper range of a pile driving impact 1.518 inches per second at 25 feet, and uses the formula $PPV_{equip}=PPV_{ref.}$ (1.518 in/sec. for a pile driver) x $(25/D)^{1.5}$. Here D is the distance from equipment to receiver. If subsequent testing shows a different vibration level at 25 feet, the 60-foot radius can be adjusted accordingly.

Bibliography

ntl.bts.gov/data/rail05/ch12.pdf. 2005.

Jones and Stokes. June 2004. Transportation and Construction-Induced Vibration Guidance Manual. Prepared for California Department of Transportation, Division of Environmental Analysis, Noise, Vibration and Hazardous Waste Management Office. Sacramento, California.

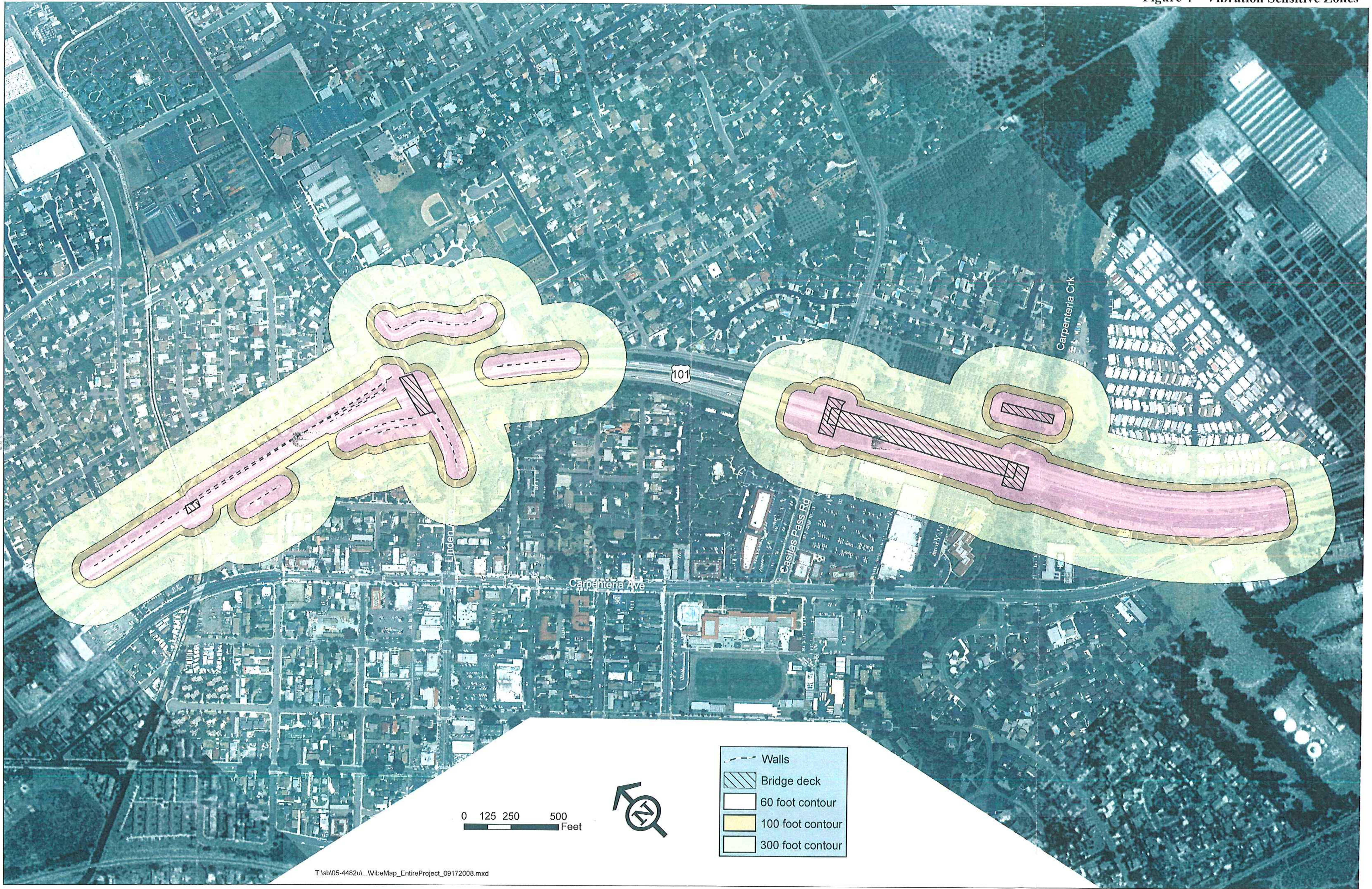
Hendricks, Rudy. January 2004. Transportation Related Earth-borne Vibrations. Technical Advisory, Vibration. Number TAV-04-01-R0201. California Department of Transportation, Division of Environmental Analysis, Noise, Vibration and Hazardous Waste Management Office. Sacramento, California.

Higa, Mitchell. December 2001. Humboldt Bay Bridges Vibration Study. California Department of Transportation, District 3, Office of Environmental Management. Marysville, California.

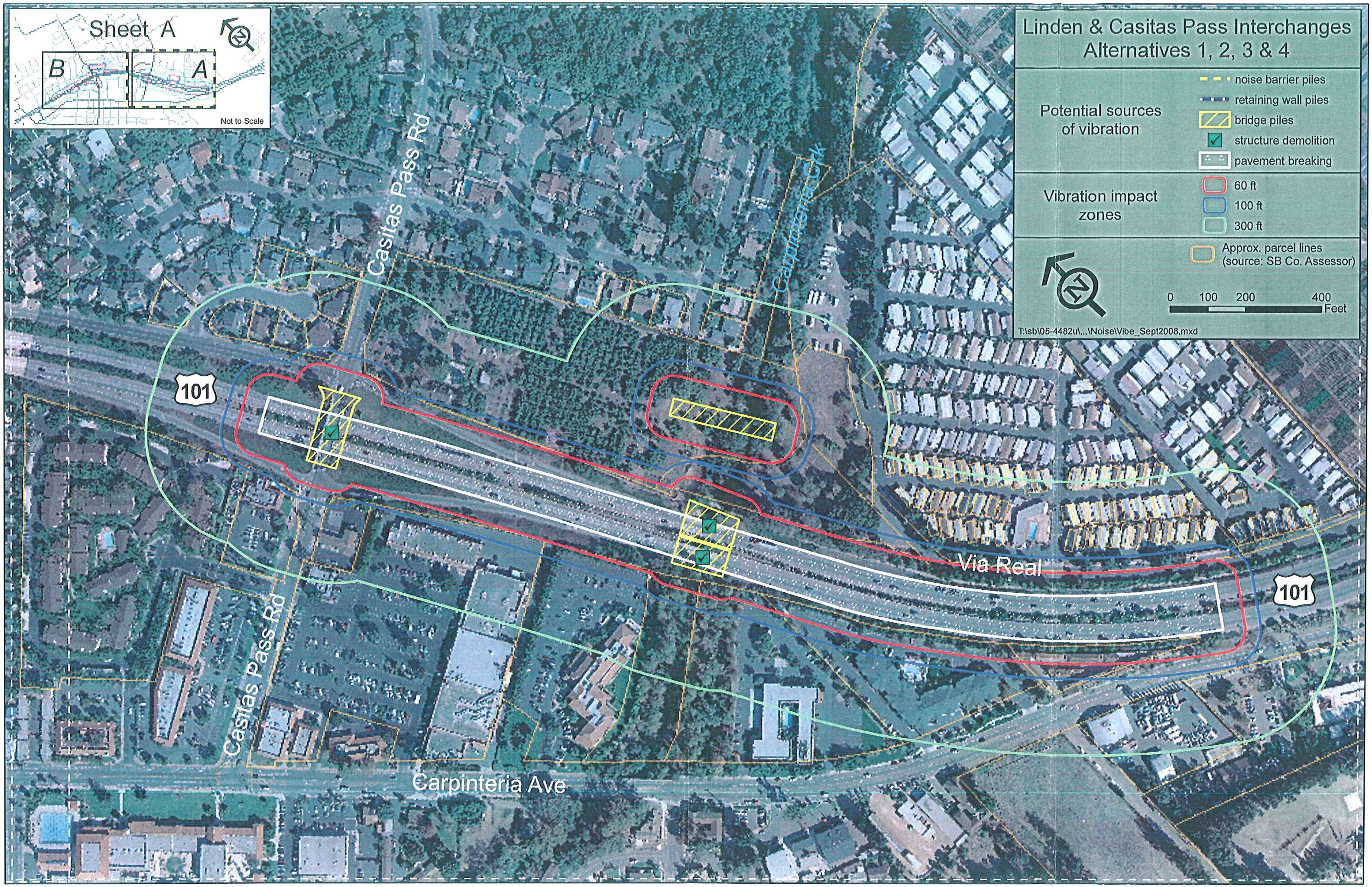
Andrews, James, P.E. April 2000. SB-101 Crack and Seat Vibration Study. California Department of Transportation, Division of Environmental Analysis, Noise, Vibration and Hazardous Waste Management Office. Sacramento, California.

Whiffen, A. C. 1971. A Survey of Traffic-Induced Vibrations (Report LR419). United Kingdom Department of Environment, Road Research Laboratory. Crowethorne, Berkshire, England.

Figure 4—Vibration Sensitive Zones



Appendix 1—Vibration Zone Mapping


Sheet A
B
A
Not to Scale
Linden & Casitas Pass Interchanges
Alternatives 1, 2, 3 & 4
Potential sources of vibration
noise barrier piles
retaining wall piles
bridge piles
structure demolition
pavement breaking
Vibration impact zones
60 ft
100 ft
300 ft
Approx. parcel lines (source: SB Co. Assessor)
0 100 200 400 Feet
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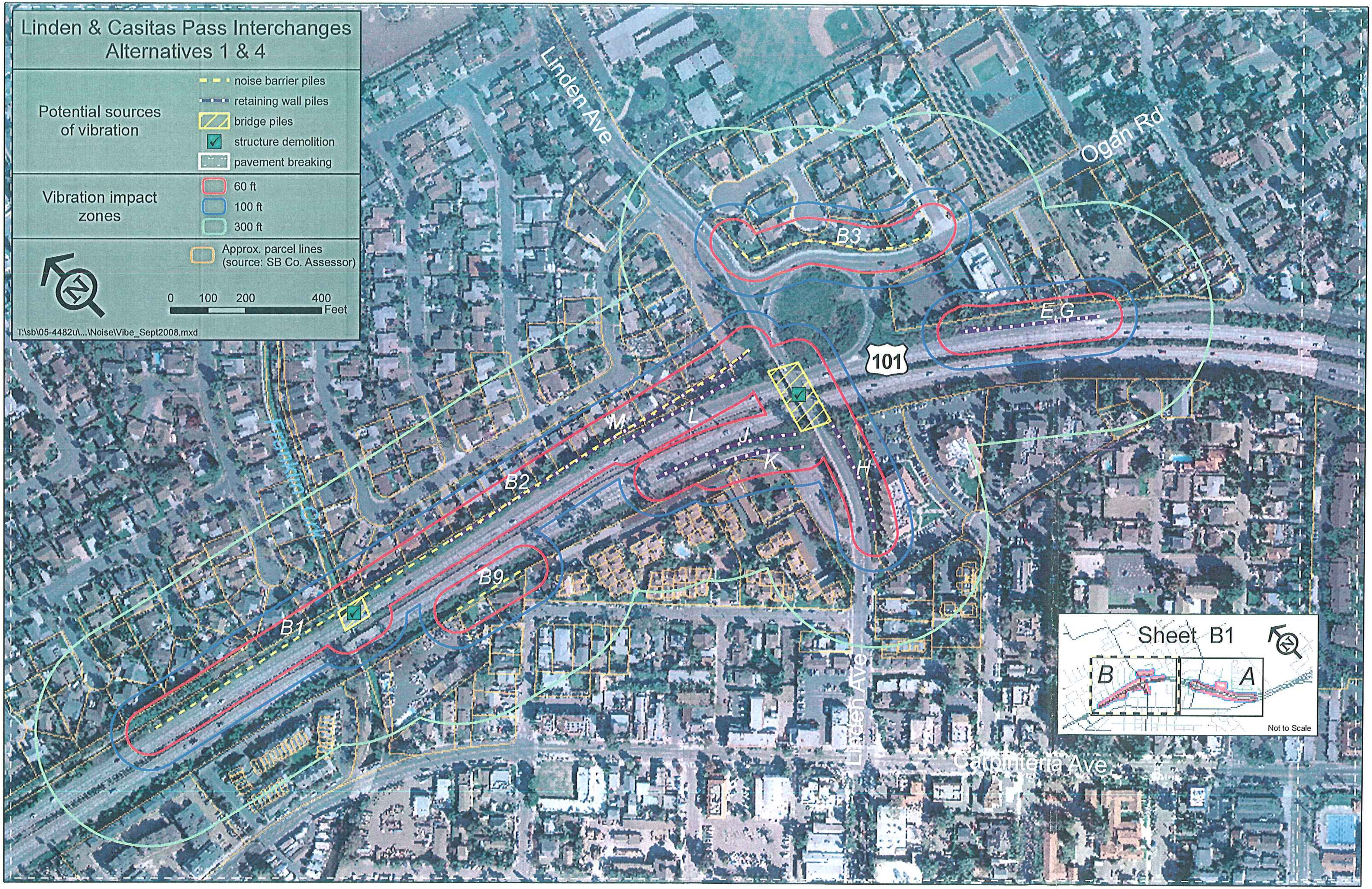
Casitas Pass Rd
Carpinteria Crk
101
Via Real
101
Casitas Pass Rd
Carpinteria Ave



Linden & Casitas Pass Interchanges
Alternatives 1 & 4
Potential sources of vibration
noise barrier piles
retaining wall piles
bridge piles
structure demolition
pavement breaking
Vibration impact zones
60 ft
100 ft
300 ft
Approx. parcel lines
(source: SB Co. Assessor)
0
100
200
400
Feet
T:\sb\05-4482u\...\Noise\Vibe_Sept2008.mxd
Linden Ave
Ogan Rd
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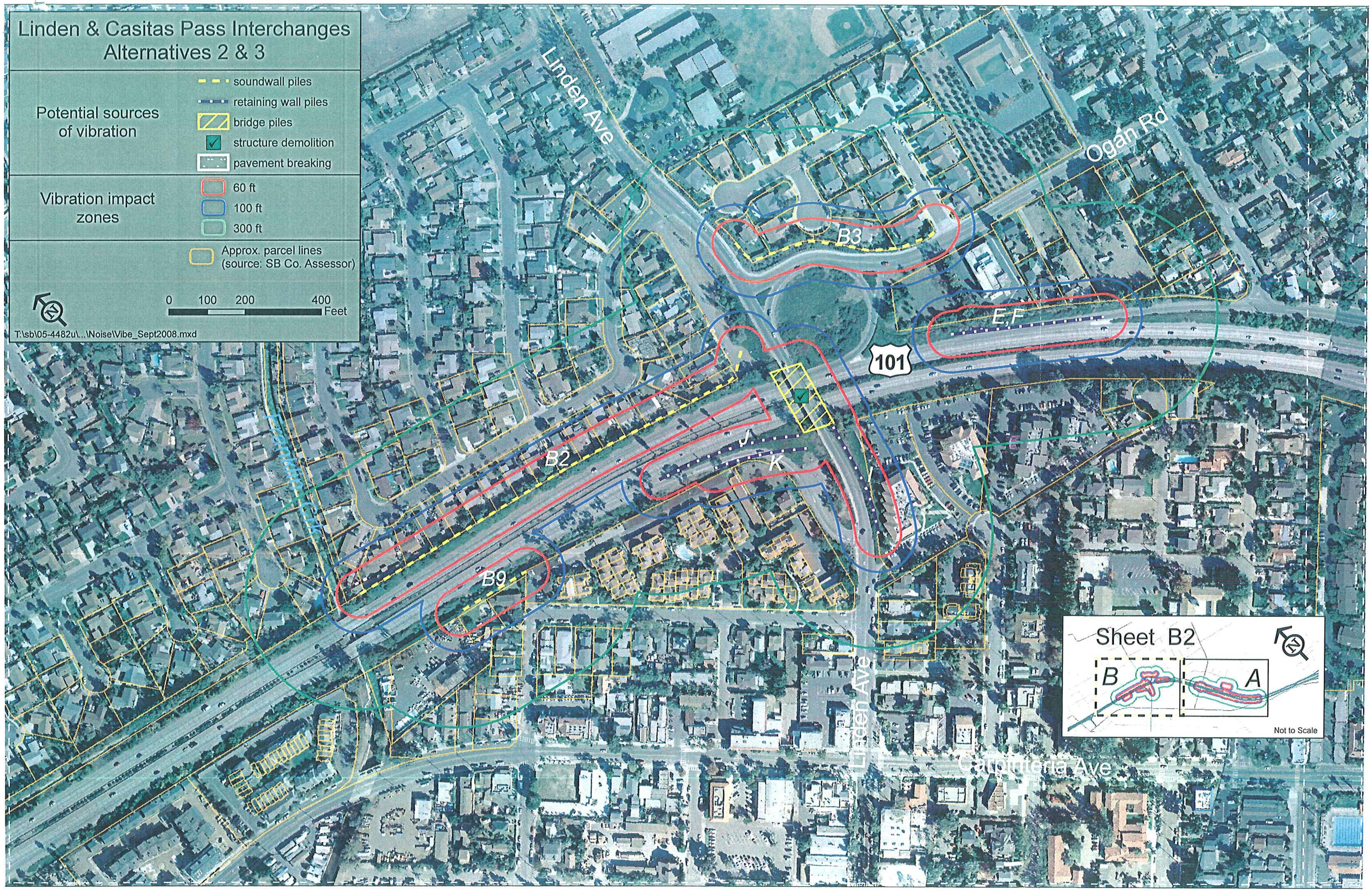
B1
Linden Ave
Carpinteria Ave
Sheet B1
B
A
Not to Scale



Linden & Casitas Pass Interchanges
Alternatives 2 & 3
Potential sources of vibration
soundwall piles
retaining wall piles
bridge piles
structure demolition
pavement breaking
Vibration impact zones
60 ft
100 ft
300 ft
Approx. parcel lines (source: SB Co. Assessor)
0 100 200 400 Feet
T:\sb\05-4482u\...\Noise\Vibe_Sept2008.mxd
Linden Ave
Ogan Rd
B3
E,F
101
B2
J
K
B9
Linden Ave
Carpinteria Ave
Sheet B2
B
A
Not to Scale